The Growing Viability of UV LED for Wide Web Coating Applications

Tuesday, October 11, 2016
Phoseon Technology

Company
Based in Portland, Oregon
UV LED Pioneer since 2002
100% Focused on UV LED
Over 242 UV LED Patents
Over 50K UV LED units Shipped
Secure Supply Chain Control
Not an OEM Machine Builder
Not an Ink, Coating, or Adhesive Formulator

Coverage
Europe
Middle East
Africa
Americas
Asia
Pacific

World-wide support

ISO 9001: 2008 Certified
## UV LED Market Activity

<table>
<thead>
<tr>
<th>Segment</th>
<th>Innovators</th>
<th>Early Adopters</th>
<th>Early Majority</th>
<th>Late Majority</th>
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<tbody>
<tr>
<td>Inkjet</td>
<td>Accomplished</td>
<td>Accomplished</td>
<td>Accomplished</td>
<td>In Progress</td>
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<tr>
<td>Screen</td>
<td>Accomplished</td>
<td>Accomplished</td>
<td>In Progress</td>
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<tr>
<td>Offset - Sheet Fed</td>
<td>Accomplished</td>
<td>Accomplished</td>
<td>In Progress</td>
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<tr>
<td>Flexo - Narrow Web</td>
<td>Accomplished</td>
<td>Accomplished</td>
<td>In Progress</td>
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<tr>
<td>Coating Lines</td>
<td>Exploring</td>
<td>Some Installs</td>
<td></td>
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<tr>
<td>Flexo - Wide Web</td>
<td>Exploring</td>
<td></td>
<td></td>
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<tr>
<td>Offset - Web</td>
<td>Exploring</td>
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UV LED in Wide Web Coating Applications
Industrial UV Energy Sources

- **Voltage Arc/Electrode (1940s)**
- **Microwave (1970s)**
- **UV LED (2000s)**
Conventional UV Energy Sources

Voltage Arc Powered Lamp (Electrode)

Microwave Powered Lamp (Electrode-less)
UV LED Energy Sources

**Electrons**
- Anode (+)
- Cathode (-)
- (+) Terminal of DC Voltage Supply
- (-) Terminal of DC Voltage Supply

**Current**
- UV Photons

**UV Photons**

www.phoseon.com
UV LED Energy Sources
Characterizing UV Sources

- **Wavelength (nm)** - distance between corresponding points of a wave.

- **Peak Irradiance (Watts/cm²)** - radiant power arriving at a surface per unit area.

- **Energy Density (Joules/cm²)** - radiant energy arriving at a surface per unit area.
Materials must be formulated to take advantage of the relatively narrow band of UV LED wavelengths.
UV LEDs Continue to Increase in Output

- 365 nm UV LED systems emit:
  - 8 Watts/cm²
  - 12 Watts/cm²

- 385, 395, and 405 nm UV LED systems emit:
  - 16 Watts/cm²
  - 24 Watts/cm²

- Laboratory LED work is being done at “much higher” levels.
- Arc lamps emit up to 3 Watts/cm² typically.
- Microwave lamps emit up to 5 Watts/cm² typically.
**UV LED Spectral Output**

- Divergent light sources
- Emitting angles vary
- Location of peak irradiance a factor of optics (3 - 5 mm typical, rod lens extends peak zone)
- Irradiance (Watts/cm²) **decreases** with distance
- Total energy density (Joules/cm²) at cure surface **remains constant** with distance
- Uniformity at cure surface **improves** with distance

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**Irradiance @ Glass = 100%**
- Projected Area = 7.5 cm²
- Power = 30 Watts

**Irradiance @ 6 mm = 50%**
- Projected Area = 15 cm²
- Power = 30 Watts

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Flat Glass  
Angle Reduction  
Rod Lens
Uniformity Along Length of Single UV LED Source

Distance vs. Uniformity (Normalized)

Uniformity Improves with Distance from LED Source
Uniformity Along Length of Scaled UV LED Sources

Scaled Uniformity (Normalized)

Scaled Lamps are Mounted End-to-End for Longer Lengths
Thermal Management is Critical

- This is not radiated IR energy but energy created by electrical inefficiencies.
- Approximately 30% of input power is converted to usable UV output.
- Approximately 70% of input power is converted to unwanted heat.
- Cannot exceed maximum LED junction temperature.
- Cooling is designed to optimize the efficiency of the LEDs.
- Cooling can be air or liquid.
UV LED Sources - Air Cooled

- Internal Heat Sink
- Cooling Fins
- Emitting Window and Semiconductor Light Matrix (SLM) of UV LEDs
- DC Power, Control, Diagnostics
- Cooling Fans

- 365 nm @ 8 W/cm²
- 385, 395, & 405 nm @ 16 W/cm²
UV LED Sources - Liquid Cooled

- Internal Heat Sink
- Liquid Manifold
- Emitting Window and Semiconductor Light Matrix (SLM) of UV LEDs
- Liquid Cooling Tubes
- DC Power, Control, Diagnostics

365 nm @ 12 W/cm²
385, 395, & 405 nm @ 24 W/cm²
Integration Components

- LED Source
- DC Power and Control
- Mounting Bracket
- Cooling System
- DC Power and Data Cables
UV LEDs are High Tech Electronics

The construction and operation of a UV LED curing system has more in common with a smart phone and a tablet than with a microwave or an arc lamp.
Manufacturing, Reliability and Quality

**Sourcing**

- Dual sourced components
- Tight specifications
- Rigid qualifications

**Manufacturing**

- Clean-room environment
- Workstations cells
- Calibrated instruments

**Testing**

- Burn-in
- Recalibration
- Packaging
- HALT & Environmental

**UV LED Sources Must be Built & Tested to Semiconductor Standards**
# UV LED Curing Benefits

<table>
<thead>
<tr>
<th>BENEFIT</th>
<th>FEATURE</th>
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<tbody>
<tr>
<td></td>
<td>Controlled curing irradiance.</td>
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<tr>
<td>Operating Economics</td>
<td>Faster speeds. Energy efficient.</td>
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<td>Long lifetime &amp; low maintenance.</td>
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<td>Low operating temperatures.</td>
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<td>Lower total cost of ownership.</td>
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<td>Environmental Advantages</td>
<td>Mercury &amp; ozone free. Safe UV-A wavelength.</td>
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<td>Near-ambient housing temp.</td>
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<td>Workplace safety.</td>
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<tr>
<td>Ease of Use &amp; Integration</td>
<td>Solid-state. Instant ON/OFF curing.</td>
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<td>No warm-up/cool-down cycles.</td>
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<td>No shutters or exhaust duct.</td>
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More Value Delivered Every Year

UK LED System Output

- Air Cooled
- Water Cooled

Performance increases every year as costs decrease.
Summarizing the State of UV LED Technology

- UV LED Systems
  - Irradiance (Watts/cm²) and energy density (Joules/cm²) continue to increase
  - Available form factors expanding
  - Reliability, efficiency, and life of sources increasing
  - Costs decreasing
  - Growing number of suppliers (LED, OEM, Formulator)
  - UVB and UVC Sources 3 to 5 Years Away
  - UV LED form factors and pricing structures now suitable to wide web.

- UV LED Irradiance ramps UP/DOWN with web speed.

- UV LED curing is commercially used for inks, adhesives, over protective varnishes, PSAs, and B-Stage gel coatings.

- Functional coatings and hard coats currently in development (lab, pilot line, and production line trials).

- Formulation development tends to be end-user driven.
Thank You.

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